

The Impact of Senior Executives' Perceptions of Sustainability on the Level of Green Technological Innovation in Enterprises

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Abstract. Regarding the background of "dual carbon" and high-quality development, it is a hot topic for both academics and industries about corporate green transformation. Based on hierarchical theory, this paper selects Chinese A-share listed companies from 2014-2024 as its research sample, empirically examines the effect of senior executives' green awareness on firms' level of green technological innovation, and further explores the mediating role of ESG performance. The findings show that: (1) senior executives' green awareness exerts a significant positive driving effect on a firm's level of green technological innovation, and this dominant influence remains robust under stability tests conducted with a shorter sample interval. (2) The results of the mediation analysis indicate that ESG performance acts as a crucial 'bridge' between executives' green awareness and the level of corporate green technological innovation; that is, executives' green awareness significantly enhances the firm's substantive green innovation output by optimising its overall performance across environmental, social and governance dimensions. (3) Heterogeneity analysis reveals that polluting firms are more sensitive and responsive to incentives for green innovation than non-polluting firms.

Keywords: executives' green awareness, corporate green technological innovation levels, corporate ESG performance, corporate governance

1. Introduction

In recent years, with the introduction of the 'Dual Carbon' targets, China's comprehensive green transition in economic and social development has reached an important stage. Enterprises are the main actors in economic activities and a significant source of carbon emissions; therefore, whether enterprises can successfully carry out their own green transitions is closely related to how well they implement the national 'Dual Carbon' strategy and achieve sustainable development goals. In this process, green technology innovation is generally considered the most important way for companies to become low carbon, improve resource use efficiency, and get long-term competitive benefits. Today, green innovation has become the core pathway for enterprises to achieve sustainable development and a key strategy for building long-term competitive advantages [1]. However, green technological innovation requires substantial research and development costs, and its returns are

uncertain [2]. As the key decision-makers in corporate strategy, the depth of senior executives' understanding of and the priority they attach to green development directly influence the direction of corporate resource allocation and the choice of innovation strategies, thereby determining the actual effectiveness of a company's green technological innovation. Consequently, clarifying the intrinsic relationship between senior executives' green awareness and a company's level of green technological innovation, and exploring the underlying mechanisms, holds significant theoretical and practical significance for promoting corporate green transition and contributing to the realisation of the national 'Dual Carbon' goals.

Use Chinese A-share listed company from 2014-2024 as the research object, this paper is to empirically study the effect of senior executive's green consciousness on corporate level of green technology innovation and its internal mechanism. The marginal contribution of this study mainly lies in these three points: Firstly, it broadens the scope of research into what drives corporate green technological innovation by showing how senior executives' green awareness affects such innovation; secondly, by incorporating corporate ESG performance as a mediator, the study comprehensively analyzes the role of executives' green awareness in promoting green technological innovation, thereby enhancing the theoretical basis of related studies; thirdly, the findings provide a theoretical reference for enterprises to optimize the composition of their executive teams and enhance the level of green awareness among management to drive green technological innovation.

2. Theoretical analysis and research hypotheses

2.1. The impact of senior executives' green awareness on the level of corporate green technological innovation

The High-Level Echelon Theory posits that senior managers are not entirely rational economic decision-makers; their personal experiences, cognitive patterns, values and risk preferences profoundly influence corporate strategic decisions and organisational outcomes. With regard to the career trajectories of senior executives, it is widely accepted in academia that those with diverse professional backgrounds experience variations in the depth of their understanding of changes in both the external and internal environments; simultaneously, work experiences accumulated across different positions, roles and industries shape distinct styles of information filtering and interpretation, which in turn influence corporate strategic decision-making [3]. According to strategic cognition theory, the subjective perceptions of senior executives serve as antecedent variables driving corporate decision-making and operational behaviour; managers shape the organisation's strategic choices and facilitate the implementation of operational activities by decoding and interpreting stimuli from the external environment [4]. Furthermore, the natural resource-based view emphasises that the sustainable competitive advantage of future organisations will stem from their resources and capabilities in responding to a favourable natural environment [5].

On the one hand, executives with green cognition are better able to deeply integrate green innovation into product development and business process re-engineering: by launching low-energy-consumption, low-pollution green products, they can tap into emerging markets, meet stakeholders' green demands, stimulate customer purchasing intent, and increase the firm's market share [6]. On the other hand, based on resource-based theory, green innovation possesses the characteristics of value, scarcity and foresight, enabling enterprises to accumulate heterogeneous resources and key capabilities, thereby forming a competitive advantage that is difficult to imitate. Consequently, executives with a green mindset regard green innovation as the core driving force behind corporate

development, promoting the implementation of management philosophies and their transformation into actual productivity, thereby assisting enterprises in continuously seizing market opportunities, integrating internal and external resources, and enhancing resource utilisation efficiency [7]. At the same time, sustained green R&D innovation drives the optimisation and transformation of industrial structures, cultivates new drivers of value growth, steadily improves operational performance, and ultimately enables enterprises to achieve higher levels of development through green technological innovation [8].

It can therefore be inferred that, as the key decision-makers regarding corporate resource allocation and long-term R&D investment, executives' green awareness directly influences the level of a company's green technological innovation. Based on the aforementioned theories, this paper proposes the following research hypothesis H1:

H1: Senior executives' green awareness has a significant positive effect on the level of a firm's green technological innovation.

2.2. The mediating role of corporate ESG

The ESG framework, as a comprehensive evaluation system integrating environmental responsibility, social responsibility and the quality of corporate governance, is increasingly becoming a core benchmark for measuring a company's capacity for sustainable development and the resilience of its long-term value.

As one of the key indicators for measuring green sustainable development, it aligns closely with China's concept of high-quality development and the 'dual carbon' targets, gradually evolving into a major driving force behind corporate strategic transformation.

Senior executives' green awareness is transmitted from the cognitive level to behavioural decision-making, indirectly influencing green technological innovation by optimising corporate ESG performance. Senior executives with a high level of green awareness typically fully recognise the organisation's social responsibility regarding environmental protection, as well as the crucial role that green development plays in the organisation's long-term competitiveness and sustainability. This awareness prompts senior executives to prioritise environmentally friendly strategies and actions across all aspects of corporate operations [9].

Following the brand-new development philosophy and goals for high-quality growth, outstanding ESG performance means that a firm is actively taking on its duties regarding nature. And so they could get policy benefits and subsidies which would bring investment into them and lower how much money they have to pay back as well as helping new ideas about making things greener [10]. From existing studies, there are mainly three ways in which ESG performance promotes corporate green technology innovation: first, ESG performance reduces debt and equity financing costs, thus driving green technology innovation [11]; secondly, ESG performance encourages companies to boost R&D investment, thereby promoting green technology innovation [12]; thirdly, ESG performance eases financial restrictions, which helps foster green technology innovation [13].

Based on this, this paper proposes research hypothesis H2.

H2: Corporate ESG performance mediates the relationship between senior executives' green awareness and the enhancement of corporate green technology innovation levels.

3. Research design and model construction

3.1. Research sample and data sources

This study focuses on Chinese A-share companies from 2014 to 2024, excluding those classified as 'ST' and those in the financial sector (as per the CSRC's 2012 industry classification). The sample was processed as follows: (1) Samples with missing data were excluded; (2) To avoid the interference of outliers in the empirical analysis, the 1 per cent and 99 per cent trim-tail methods were applied to continuous variables. The method for measuring executives' green awareness in this study utilised raw data obtained through text analysis of listed companies' annual reports; raw data on corporate green technological innovation were sourced from CRDNS; and other data, such as control variables, were sourced from the CSMAR database. A total of 28,891 data samples were collected and analysed using Stata 18 software.

3.2. Definitions of key variables

3.2.1. Dependent variable: corporate green innovation level (GIP)

The level of corporate green innovation mentioned here refers to the innovative activities carried out by companies in terms of their products, processes, management or services with the aim of reducing environmental impact. In this study, GIP is measured by the number of green patent applications filed by the enterprise; this indicator can reflect the enterprise's substantive innovative output in the field of green technology in a relatively objective and timely manner [14]. A higher GIP value indicates stronger corporate green technological innovation capacity and a higher level of green innovation.

3.2.2. Explanatory variable: executive green perception (EGP)

In this paper, 'executive green perception' refers to the senior management team's sensitivity to, value orientation towards, and cognitive framework regarding environmental sustainability issues; it reflects their subjective willingness and ability to integrate ecological conservation principles into corporate strategic decision-making. This study uses the proportion of terms related to executive green perception in the full text as a metric [15]. A higher EGP value indicates a greater level of attention paid to green issues by the executive team.

3.2.3. Variable definitions

Table 1. Table of variable definitions

Variable Name	Variable Definition	Variable Symbol	Measurement Method
Dependent variable	Level of green technology innovation	GIP	ln(number of green patent applications filed by enterprises + 1)
Explanatory variables	Senior management's awareness of green issues	EGP	Proportion of text comprising terms related to executives' green awareness (%)

Table 1. (continued)

Mediating variable	Corporate ESG performance	ESG	Huazheng ESG Rating Index
	Company size	Size	ln(Total Assets / Number of Employees)
	Profitability	ROA	Net Profit Margin on Total Assets
	Company age	Age	ln(Age of the company)
Control variables	Cash Flow Adequacy	CFOA	Net cash flow from operating activities / Total assets
	Tobin's Q	Tobin Q	Tobin's Q
	Proportion of independent directors	Indir	Number of independent directors / Total number of directors
	Shareholding ratios of the top ten shareholders	Top 10	Shareholding ratios of the top ten shareholders

3.3. Model specification

In order to study how much senior executive's green awareness affects the amount of a company's technological innovations that are environmentally friendly, we made up an equation where GIP is what it depends on (dependent) and EGP is something else which has its own meaning here. We also built another regression model with ESG as mediator variable. Furthermore, this study grouped all control variables under the name 'Controls' and controlled for industry and year effects in the models. See Models (1), (2) and (3) for details.

$$GIP_i = \beta_0 + \beta_1 EGP_i + \sum Controls_i + \sum Industry_i + \sum Year_i + \varepsilon_i \quad (1)$$

$$GIP_i = \alpha_0 + \alpha_1 ESG_i + \sum Controls_i + \sum Industry_i + \sum Year_i + \varepsilon_i \quad (2)$$

$$ESG_i = \gamma_0 + \gamma_1 EGP_i + \sum Controls_i + \sum Industry_i + \sum Year_i + \varepsilon_i \quad (3)$$

4. Empirical results and analysis

4.1. Descriptive statistical analysis

Table 2. Descriptive statistics

Variable	N	Mean	SD	Min	p50	Max
GIP	28,887	0.410	0.860	0	0	6.850
EGP	28,891	0.005	0.0100	0	0	0.0300
ESG	28,891	73.45	5.430	56.98	73.59	87.11
ROA	28,891	0.0300	0.0600	-0.250	0.0400	0.200
Cfoa	28,891	0.0500	0.0700	-0.140	0.0500	0.250
TobinQ	28,891	2.020	1.260	0.830	1.610	8.220

Table 2. (continued)

Age	28,891	2.990	0.320	2.080	3.030	3.640
Top 10	28,891	58.17	15.51	22.75	58.79	90.89
Size	28,889	14.65	0.870	12.79	14.56	17.44
Indir	28,889	0.380	0.0500	0.330	0.360	0.570

The main table here is showing some descriptive stats about all our independent var's, dependent var's, mediating vars and control vars. Among them, GIP as the dependent variable has an average of 0.410, with a standard deviation of 0.860, ranging from 0 to 6.850; which means there are differences in how much green tech innovation exists among the companies we looked at. The mean value of the explanatory variable EGP is 0.005, its maximum does not exceed 0.1. It indicates that most senior executives' green awareness is shallow, they do not have foresight on the company's green and environmental protection aspect.

4.2. Basic regression analysis

Table 3. Basic regression analysis

	GIP	GIP
EGP	5.810*** (0.874)	5.682*** (1.296)
ROA	0.585*** (0.0871)	0.549*** (0.121)
CFOA	0.331*** (0.0841)	0.330*** (0.125)
Tobin Q	-0.0381*** (0.00423)	-0.0186*** (0.00649)
Age	-0.0782*** (0.0169)	-0.103*** (0.0254)
Top 10	-0.000134 (0.000338)	0.000360 (0.000513)
Size	0.0623*** (0.00684)	0.0669*** (0.0102)
_cons	-0.578*** (0.141)	-0.588*** (0.213)
Ind	Yes	Yes
Year	Yes	Yes
N	28883	14,165

Table 3. (continued)

R^2	0.139	0.144
adj. R^2	0.136	0.139

$p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In this table, it shows the regression outcomes of how executives' green awareness affects a company's degree of green technological innovation. From the regression results of the main explanatory variables and the main dependent variable, the regression coefficients for EGP and GIP are both 5.810, which is significantly positive. Therefore, we can conclude that if all other factors remain unchanged, executives' green awareness will have a positive effect on a firm's level of green technological innovation. The more executives who have green awareness, the higher the firm's level of green technological innovation.

4.3. Robustness analysis

To conduct robustness tests, this study shortened the original sample period from 2014–2024 to 2018–2022 and performed the regression analysis again. The regression results show that the core coefficients for EGP and GIP are 5.682, which does not differ significantly from the coefficient of 5.810 in Table 2; their significance level also remains at three stars, indicating no significant change. These results demonstrate that the core research conclusions of this paper possess strong robustness and reliability, and can provide reliable empirical evidence for related research.

4.4. Analysis of mediating variables

Table 4. Regression analysis of mediating variables

	ESG	GIP
EGP	39.24*** (5.515)	4.905*** (0.866)
ROA	17.34*** (0.549)	0.185** (0.0876)
CFOA	2.653*** (0.530)	0.270*** (0.0832)
Tobin Q	-0.431*** (0.0267)	-0.0282*** (0.00421)
Age	-0.271** (0.106)	-0.0719*** (0.0167)
Top 10	0.0374*** (0.00213)	-0.000997*** (0.000337)
Size	0.278*** (0.0431)	0.0559*** (0.00677)

Table 4. (continued)

ESG		0.0231*** (0.000924)
_cons	61.72*** (0.888)	-2.000*** (0.150)
Ind	Yes	Yes
Year	Yes	Yes
<i>N</i>	28887	28883
<i>R</i> ²	0.133	0.157
adj. <i>R</i> ²	0.130	0.154

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

This table shows the outcome of mediating regression analyses about how companies' ESG performance, bosses' eco-awareness and firm's degree of eco-tech improvement relate. Regression coefficient for executives' green awareness on the mediating variable—corporate ESG performance—is 39.24, which is greatly positive. This means that an increase in executives' green awareness will greatly improve a company's overall ESG performance. It also suggests that if executives commit to developing green things, this commitment could lead to improvements not just environmentally but socially as well as within the business itself (i.e., governance).

The regression coefficient for corporate ESG performance with respect to the level of corporate green technological innovation is 0.0231, which is significantly positive. According to the standards for identifying mediation effects, we can conclude that corporate ESG performance has some partial mediating effect in the process where executives' green awareness affects corporate green technological innovation; that is, executives' green awareness can create an indirect transmission channel through enhancing corporate ESG performance, thus promoting an increase in the level of corporate green innovation.

4.5. Heterogeneity analysis

Table 5. Heterogeneity analysis

	GIP	GIP	GIP	GIP
EGP	2.631** (1.239)	7.686*** (1.153)	5.259*** (1.580)	5.474*** (1.041)
ROA	0.191 (0.190)	0.678*** (0.0981)	1.116*** (0.202)	0.597*** (0.0936)
Cfoa	0.876*** (0.174)	0.213** (0.0957)	0.861*** (0.179)	0.0837 (0.0924)
TobinQ	-0.0348*** (0.00954)	-0.0377*** (0.00473)	-0.0665*** (0.0102)	-0.0228*** (0.00453)

Table 5. (continued)

Age	-0.0108 (0.0367)	-0.0895*** (0.0190)	-0.0160 (0.0404)	-0.187*** (0.0187)
Top 10	0.00231*** (0.000661)	-0.000774** (0.000390)	0.00166** (0.000714)	-0.00153*** (0.000380)
Size	0.0843*** (0.0152)	0.0576*** (0.00767)	0.108*** (0.0138)	0.0272*** (0.00777)
_cons	-1.031*** (0.270)	-0.463*** (0.154)	-1.492*** (0.267)	0.238 (0.178)
Ind Year	Yes Yes	Yes Yes	Yes Yes	Yes Yes
<i>N</i>	5818	23,065	8,078	20,805
<i>R</i> ²	0.115	0.143	0.237	0.144
adj. <i>R</i> ²	0.107	0.140	0.228	0.140

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In this paper, we divide the samples into polluting and non-polluting enterprises, as well as state-owned and non-state-owned enterprises, and do heterogeneity analysis on each group separately.

In the heterogeneity analysis of polluting and non-polluting firms, the regression coefficient of EGP on GIP was 2.631 ($p < 0.05$) in the sample of polluting firms, while it reached up to 7.686 ($p < 0.01$) in the sample of non-polluting firms. This shows that non-polluting companies react more quickly and actively when given encouragement for green innovation. The reason is because non-polluting firms usually have a cleaner technology base and more flexible organizational structure compared to polluting firms which show less reaction towards green technological improvement leading to smaller absolute values and lower levels of significance.

In the heterogeneity analysis of state-owned and non-state-owned enterprises, the regression coefficients of EGP on GIP were 5.259 and 5.474 respectively; both were very significant at the 1% level, and their magnitudes were also close. It means there's no big difference in how much green innovation happens between state-owned and non-state-owned companies, and they get similar results with making new kinds of tech that help protect nature.

5. Research conclusions and policy recommendations

5.1. Research conclusions

The paper took the A-shares listed companies from 2014-2024, but it excluded ST ones and also the financial sectors (according to the CSRC's 2012 classification), as our samples. We did some actual looking into how senior bosses' thoughts about being eco-friendly affected just how much tech that's environmentally friendly a business had, which got us these results: Firstly, simple regressions showed that leaders' eco-friendly feelings have a big good effect on how many eco-friendly techs a company has. And then narrowing down the sample range for robustness test makes sure those regression result are solid.

Second, mediation analysis showed that corporate ESG performance is a mediator variable that facilitates the transmission of executives' green awareness to the level of corporate green technological innovation. Lastly, heterogeneous analyses indicated that the influence of executives' green awareness on the degree of green technology innovation is greater in polluting enterprises than in non-polluting enterprises. Moreover, when we do heterogeneity tests according to ownership structure, both state-owned and non-state-owned enterprises show similar positive effects of executives' green awareness on green technological innovation.

5.2. Policy recommendations

Based on the above conclusions, this study offers the following policy recommendations. Firstly, enterprises should promote the in-depth cultivation of green development concepts among senior executives, incorporating their green awareness into the executive team development framework. For enterprises in heavily polluting industries, it is essential to focus on guiding senior executives to develop an awareness of green transition, encouraging them to proactively acquire knowledge of green development and break away from reliance on existing technological pathways, thereby narrowing the gap with non-polluting enterprises in terms of green innovation responsiveness.

Secondly, enterprises should attach great importance to the mediating role of ESG performance. They should deeply integrate ESG management into their strategic planning. Enterprises can utilise ESG targets to optimise the allocation of resources for green innovation and leverage ESG practices to drive the implementation of senior executives' green awareness, thereby fully unleashing the catalytic effect of such awareness on green innovation. At the same time, at the government level, authorities should optimise the institutional environment for green innovation and further refine incentive policies for green transition. Targeted green subsidies and tax incentives should be introduced for heavily polluting enterprises to alleviate the cost pressures associated with undertaking green technological innovation. Furthermore, mechanisms for the protection of green intellectual property rights should be strengthened to ensure that enterprises of different ownership structures and across various industries can all enhance their levels of green technological innovation by drawing on senior management's green awareness.

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